Towards a Full Body Interface to Networked Virtual Environments

http://movesinstitute.org/bachmann/bachmannresearch.html

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Immersive Interface

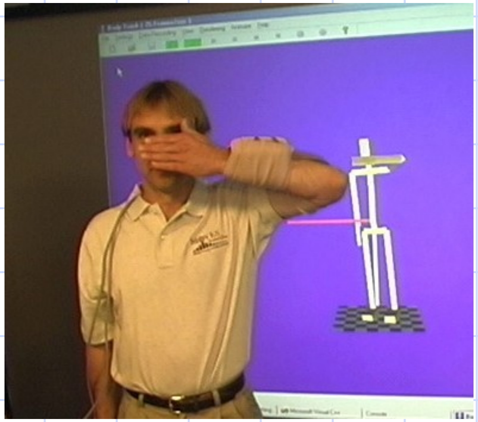
Tracking of Body posture and position allows

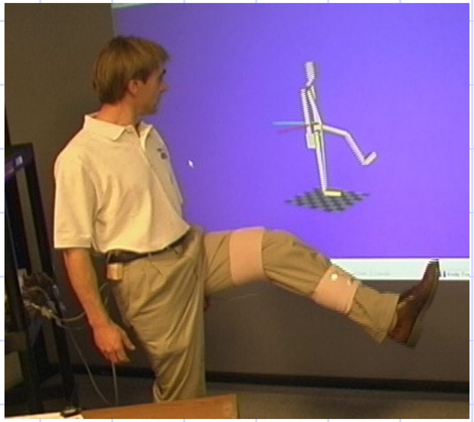
- Users to interact with a synthetic environment in a natural way
- Presentation of appropriate information to the senses
- Animation of avatars which visually represent the action of a user to their self as well as to other users of the environment.

Basic Principles of Inertial/Magnetic Body Tracking

Based on the passive measurement of physical quantities directly related to motion and attitude. (“Sourceless”)

- Each segment is oriented independently
- Segments are positioned relative to each other by adding rotated limb-translation vectors
- Requires the use of complementary sensor types to eliminate drift errors
- Position data for a single reference point is needed to place the avatar within a virtual environment.





Sourceless

- All delays are due to data processing and transmission
- No occlusion problems
- Minimal interference and noise
- Unlimited range

Where we are

- To make possible sourceless full body tracking, the MOVES Institute has conducted research in
  - Algorithms
  - Sensors
  - Calibration
  - Personalized Avatars

- This work has prepared us to construct a full body tracking system.

Complementary Attitude Filter

The quaternion-based complementary estimation filter estimates attitude using

- 3 orthogonally mounted angular rate sensors
- 3 orthogonally mounted linear accelerometers
- 3 orthogonally mounted magnetometers

Combining of filter inputs is treated as a parameter optimization problem

- Error minimization is accomplished by adjusting the derivative of the estimated orientation quaternion, “*q-hat*”

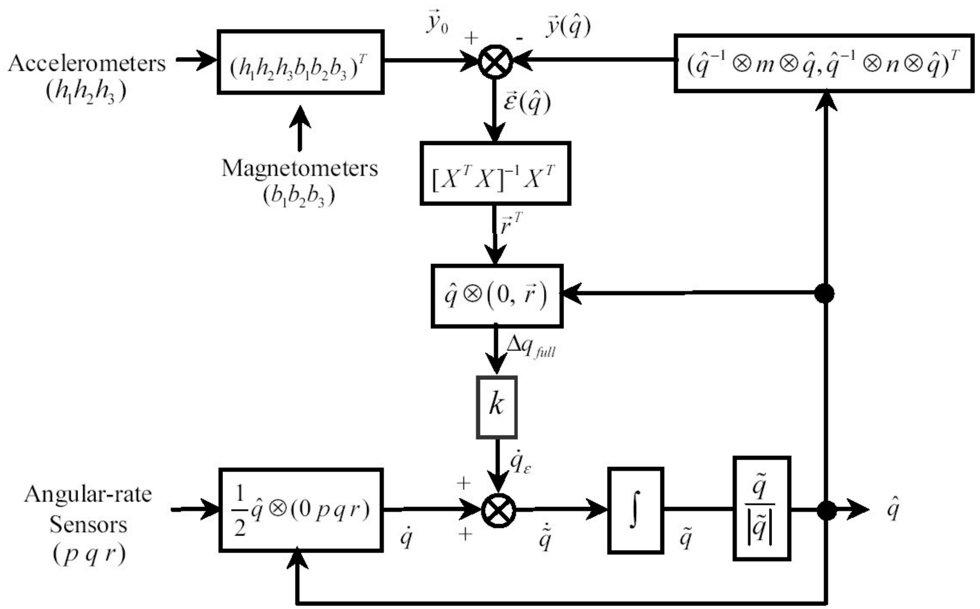
<u>Tracks through all orientations without singularities</u>

<u>Continuously corrects for drift</u>

<u>Computationally efficient</u>

- Recent discoveries have lead to order of magnitude reductions in calculations to be preformed

<u>Dynamically and statically accurate</u>



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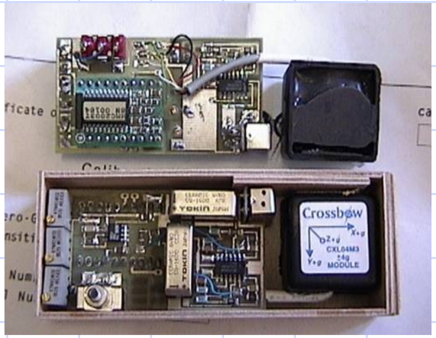
MARG Sensors

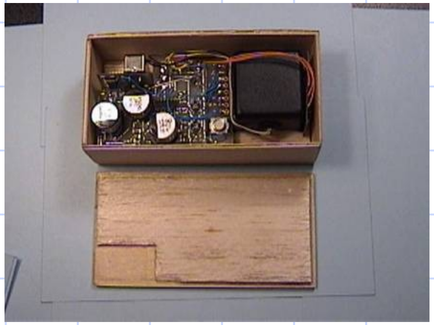
In order to investigate filtering algorithm alternatives, it has been necessary to develop sensors in house.

- Sensor components include
  - Three axis magnetometer
  - Three axis accelerometer
  - Three axis angular rate sensor

Several generations have been developed

- Each generation has had
  - Reduced form factor
  - Superior signal process capabilities
- Both analog and digital filtering of angular rate data have been explored
- To date all MARG sensors have had analog output
  - Required manual reset of magnetometers





Sensor Calibration
Human Model Calibration

Calibration of inertial sensors requires determination of
- Sensor Nulls
- Sensor Scale Factors

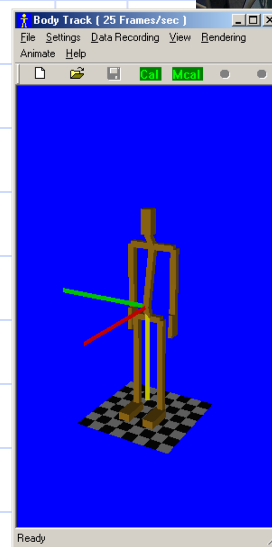
MARG type sensors can be calibrated by had without the use of any specialized equipment
- Initial results indicate that hand calibration makes possible the same accuracy as more involved machine calibration

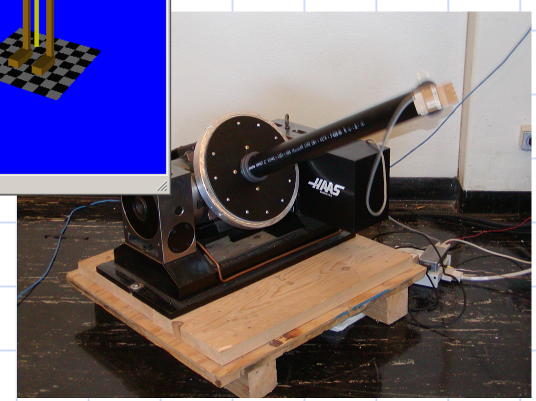
In general body segment frames are not actually aligned with the associated sensor frame

This relation is expressed by an “offset” quaternion.

The offset may be calculated by placing each limb segment in a know orientation

All difference between the reported orientation and the actual orientation is due to the offset





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Realistic Human Avatars

Realistic avatar motion requires that the model be properly sized to the user

Creation and rendering of realistic personalized avatars for use as virtual body representations is often too complex for real-time applications

- Laser-scanning captures human body surface anatomical information accurate to the scale of millimeters.
- Laser scan data complexity must be reduced so that the avatars can rendered efficiently
- Data must be organized and segmented for full articulation and realistic movement.

Result is an articulated VRML/H-Anim 1.1 avatar

A Full-Body Motion Tracking System

Building of a full-body motion tracking system based on inertial/magnetic sensors is expected to take place over the next year.

- Testing of full system expected to begin in the summer of 2003.

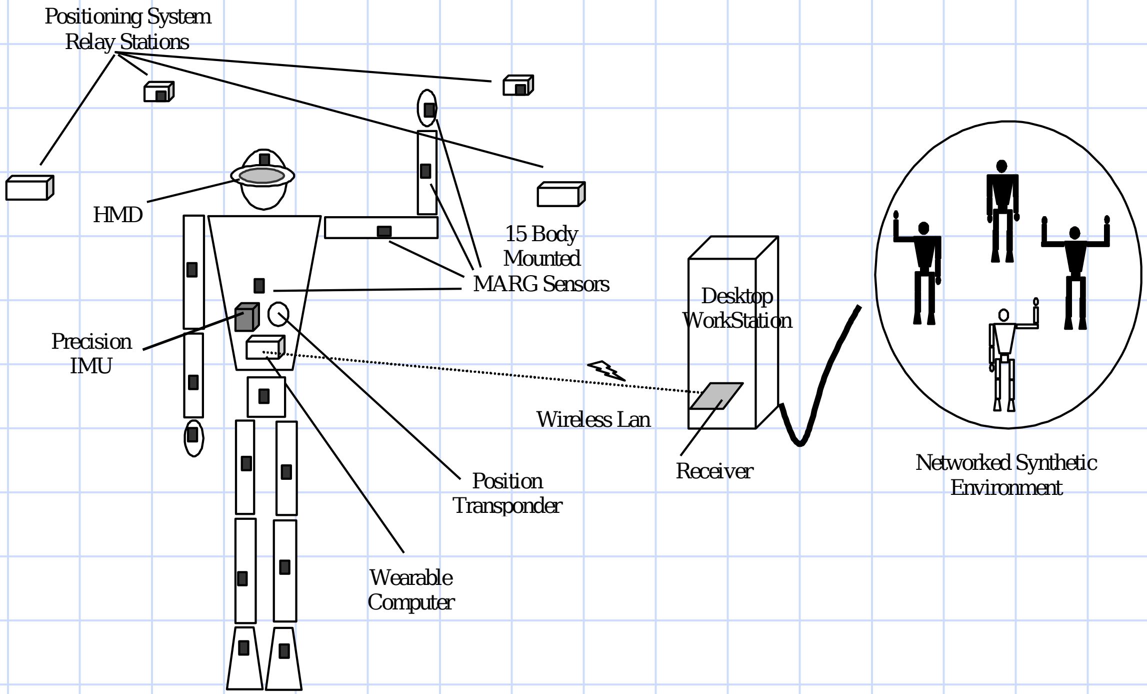
Completion of the system will require work in numerous areas.

- Sensor design and hardware integration
- Filtering algorithm implementation
- Sensor interface design and wireless communication
- Positioning system integration
- Realistic avatar development
- Networked VE integration

Full-Body Motion Tracking System Overview

In the full body tracking system

- MARG sensors used to determine posture
- Position of one point on the body may be tracked using an RF tracking system
- Position may also be determined through the use of a precision IMU and gait measurement

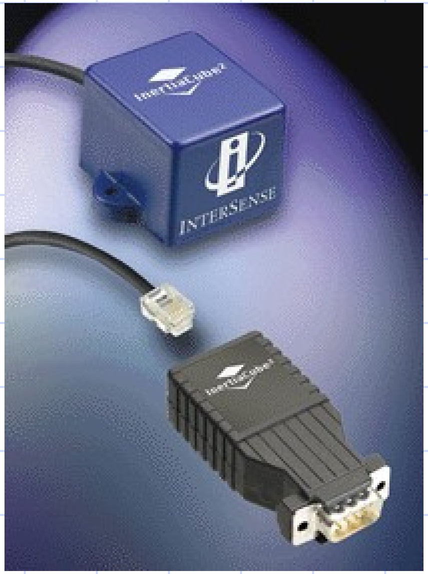


Systems Integration

- Tethered systems increase user encumbrance and cancel the advantages that a sourceless tracking system has to offer
  - Incorporation of a wireless technologies will eliminate this problem
- Systems integration will require merging and processing data from multiple sources
  - MARG data from 15 sensors in either raw or quaternion form
  - RF positioning system data
  - Precision IMU heading and attitude data
  - Graphical data for Head Mounted Display
- A data control unit will be constructed to collect data from all sensors
  - The data control unit will output the data in USB format to a wearable PC.
  - Wearable PC will transmit the tracking data using an 802.11b wireless PCMCIA card.
- Implementation of the data control unit may require development of a specialized control protocol

Inertial/Magnetic Sensors
InterSense IS-300 InertiaCube

- Extended Kalman filter used to filter sensor data
- Available with an RS-232 serial interface and control dynamic link library (DLL)
  - Maximum Angular Rate: 1200º per second
  - Minimum Angular Rate: 3º per second
  - Static Accuracy: 1º rms
  - Dynamic Accuracy: 3º rms
  - Update Rate: 120 Hz
  - Latency: 8 milliseconds
  - Power: 6 VDC via AC Adapter, 100 milliamps
  - Approximate Form Factor: Enclosure 1.3” x 1.14” x 0.94” (base 1.6” x 1.7”) Volume 1.4”[2]



Inertial/Magnetic Sensors
Microstrain 3DM-G Gyro Enhanced Orientation Sensor

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Embedded microcontroller performs orientation calculations using an adhoc complementary filter

- Digital Output, RS-232 & RS-485
- Maximum Angular Rate: 300º per second
- Accuracy: ±5 degrees
- Update Rate: 100 Hz (digital RS-232)
- Latency: ?
- Power: 5.2 VDC minimum, 90 milliamps
- Form Factor: Enclosure 2.5” x 2.5” x 0.9”

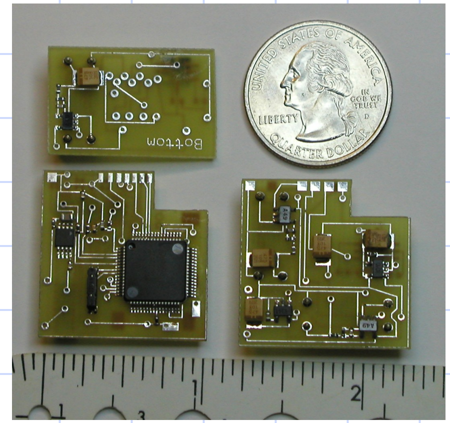
(base 2.5” x 3.5”) Volume 5.625”2

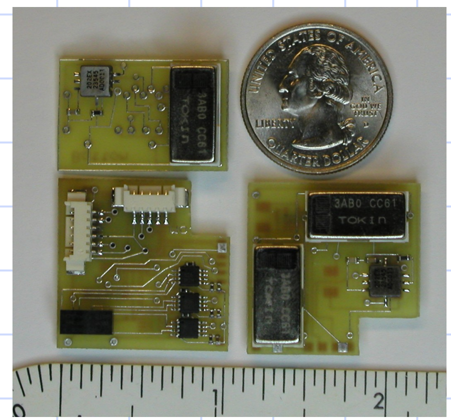
Inertial/Magnetic Sensors MARG 3

Developed at the Naval Postgraduate School by the MOVES Institute and McKinney Technology

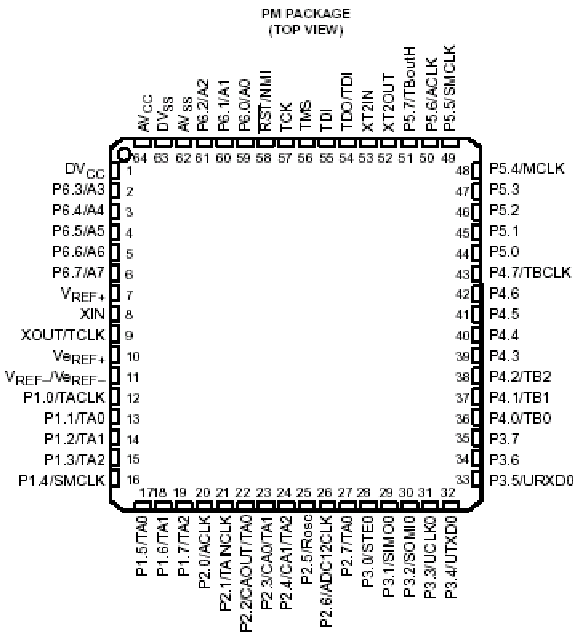
Attitude estimates made by a quaternion-based complementary filter

- Onboard microprocessor
- Digital output (automatic mag reset)
- Accuracy: Less than 1 degree rms
- Latency: minimal
- Update Rate: 100 Hz
- Power: 12 vdc, 50 ma
- Form Factor: Less than one cubic inch





MARG 3 Microprocessor Programming



Microprocessors onboard the MARG sensor can reduce bandwidth requirements and distribute the computational load by performing multiple functions

- Analog to digital conversion
- Implementation of the filtering algorithm
- Packaging of estimation data for network transmission

Proposed microprocessor:

- Texas Instrument MSP430F149 16-Bit Ultra-Low-Power Microcontroller
  - RAM (Bytes) 2048
  - ADC 12 bit
  - UART hardware

Precision Gyros

The use of magnetometers makes MARG sensors susceptible to variations in the local magnetic field

Fiber-Optic and Ring-Laser gyros have steadily come down in both size and cost

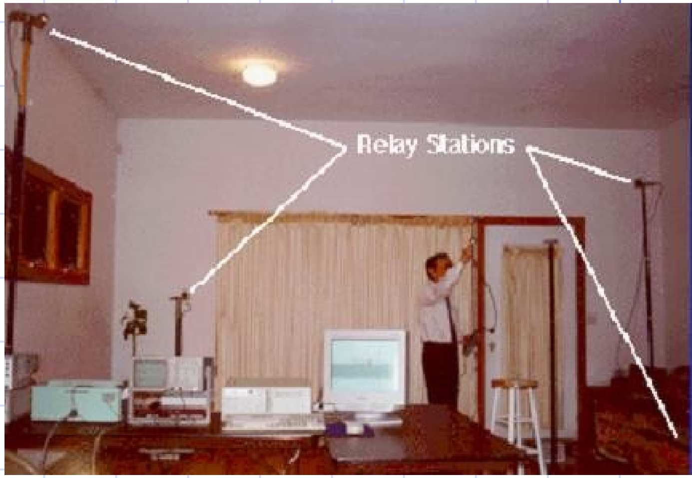
- Litton LN200 Ring-Laser Gyro Based IMU 20-25K (± 1°/hour)
- KVH E-Core Fiber-Optic Gyro Based IMU 10K (± 20°/hour)

In a “backpack” coupled with a MARG sensor, a precision gyro could be used to create a stable heading reference

- May allow full tracking without a positioning system through gait measurement

RF Positioning

- Inertial/Magnetic sensor can only be used to track body posture
  - Position can be dead reckoned for short periods
- To accurately place an avatar within a virtual environment the x y z position of one point on the body of the user must be tracked



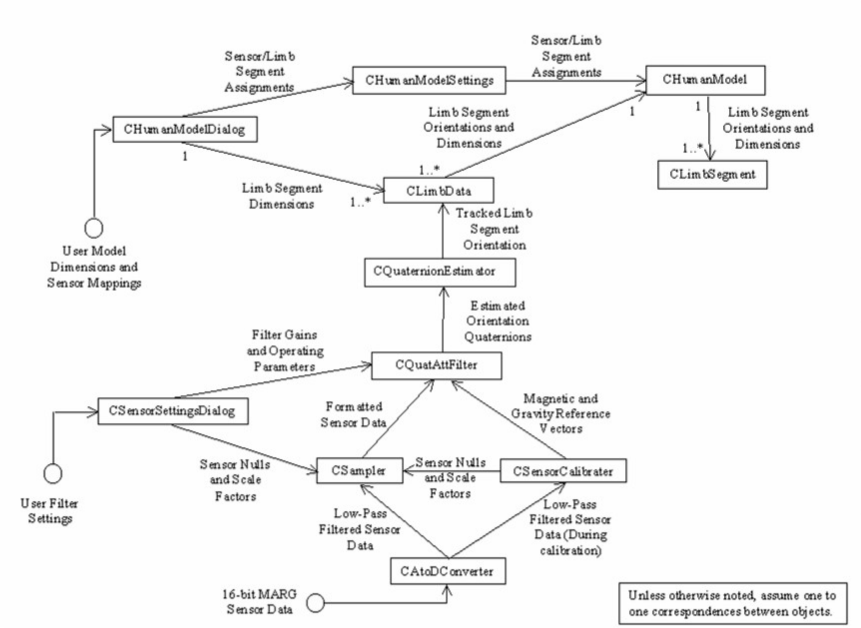
- Radio Frequency (RF) positioning is very fast and able to operate over a wide area with minimal line of sight restrictions.
  - Spread spectrum systems are nearly impervious to noise and interference
- Under an ONR grant APSI has developed a practical RF positioning system

Software Architecture

Previous version of body tracking software implemented as a single monolithic program

Software under development will be modular and network based

- Data Capture
- Data Filtering
- System calibration
- Avatar animation and rendering



Avatars

VRML Avatar work is still time consuming and must be done largely by hand.

- When segments are moved from the initial scan position “tears” can be seen at the joints where segments are connected.
- Automatic segmenting of the body model is being explored.
- Algorithms that allow deformation of the model without tearing of the skin are currently under investigation.

Precision measurement of limb segments will make possible accurate gait measurement

Summary

- Inertial / magnetic (MARG) body tracking avoids the shortcomings associated with current technologies.
- It is capable of providing wide area tracking of multiple users for networked synthetic environment applications
  - Avatar posture is determined using only orientation data
  - The avatar can be place by tracking the position of one point on the body
- Use of a single precision gyro may allow correction for variations in the local magnetic field
  - Position may be determined through dead-reckoning and gait measurement
- Major software and hardware improvement underway to achieve full body wireless tracking
  - Prototype demonstration expected by summer of 2003

Sponsors

U. S. Army Research Office (ARO)

U. S. Navy Modeling and Simulation Management Office (N6M)

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